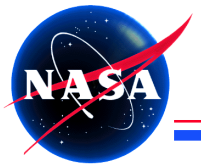

IKONOS-based Simulations of Landsat 7 VNIR Data: Comparison with Actual, Coincident Images

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March 19 - 21, 2001

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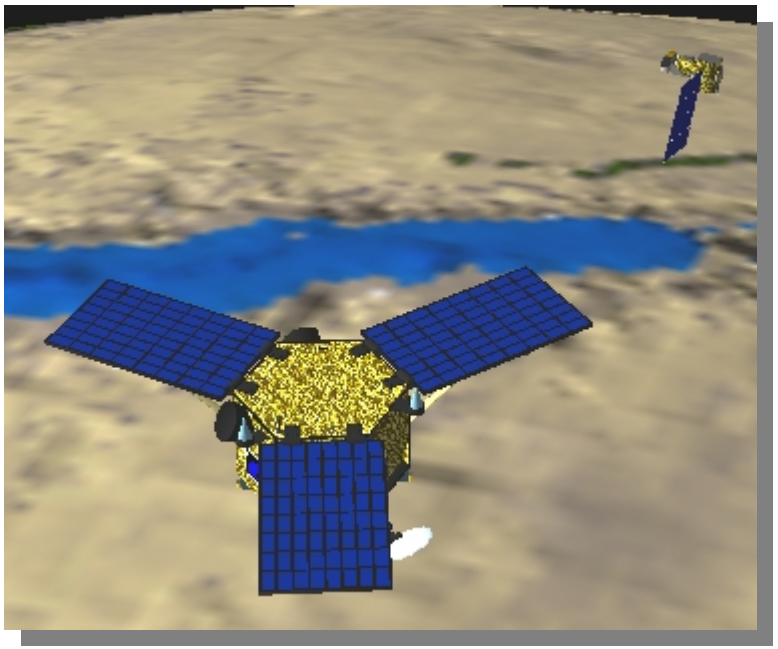
SDSU

IKONOS V&V: Landsat 7 Simulations

Stennis Space Center

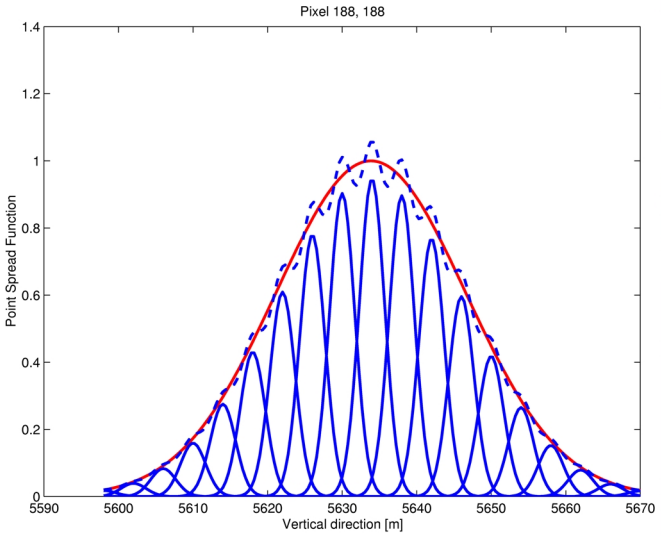
- IKONOS images were used to simulate four VNIR bands of Landsat 7 level 1G images (similar processing level: radiometric correction, georeferenced with cubic-convolution resampling, UTM projection)
- In year 2000, 92% of Landsat 7 images distributed by USGS EROS Data Center were on the level 1G
- Simulations validated by comparing results with actual coincident Landsat 7 images
- Results provide insights on radiometric calibration, spatial resolution, and geolocation accuracy of the image products

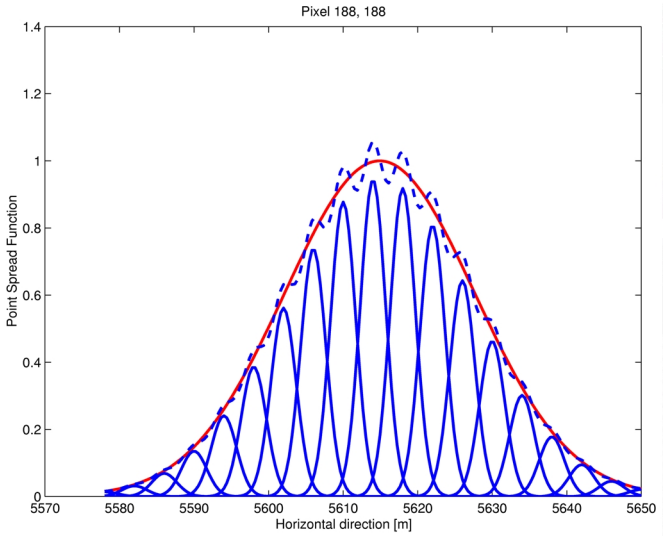


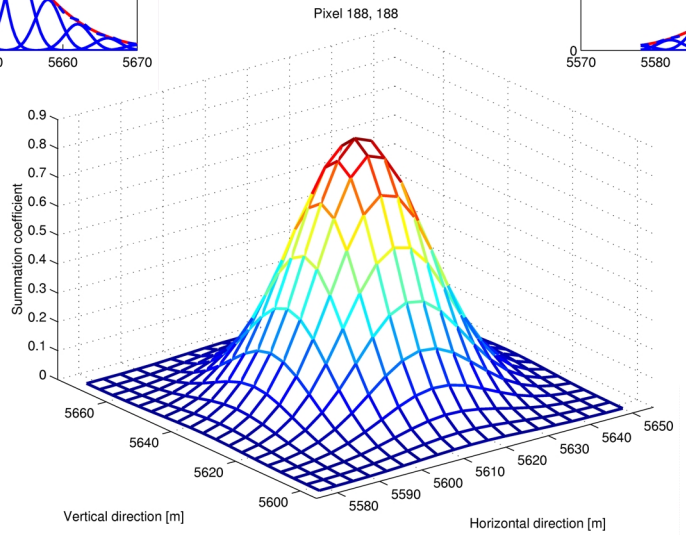
December 14, 2000
Distance of 35 km

Simulation Algorithm: PSF Synthesis

Stennis Space Center







For each spectral band, the Landsat 7 image (I') is simulated by linear combination of the IKONOS image (I) pixels:

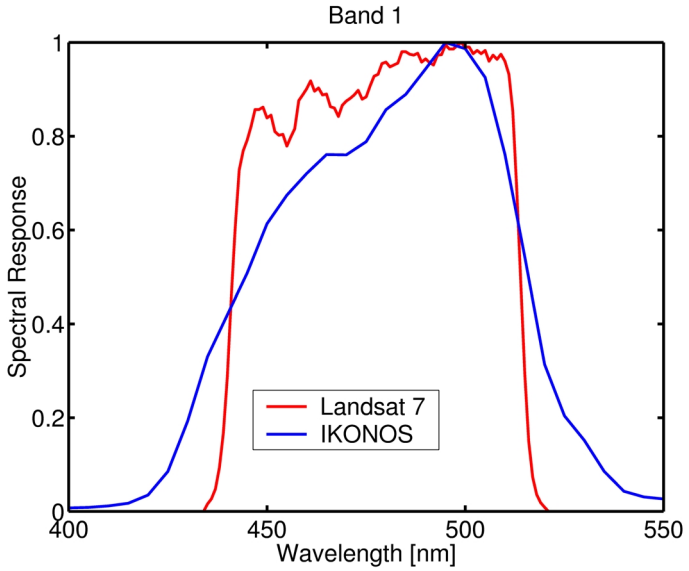
$$I'_{kl} = \frac{\sum_i \sum_j c_{ijkl} I_{ij}}{\sum_i \sum_j c_{ijkl}}$$

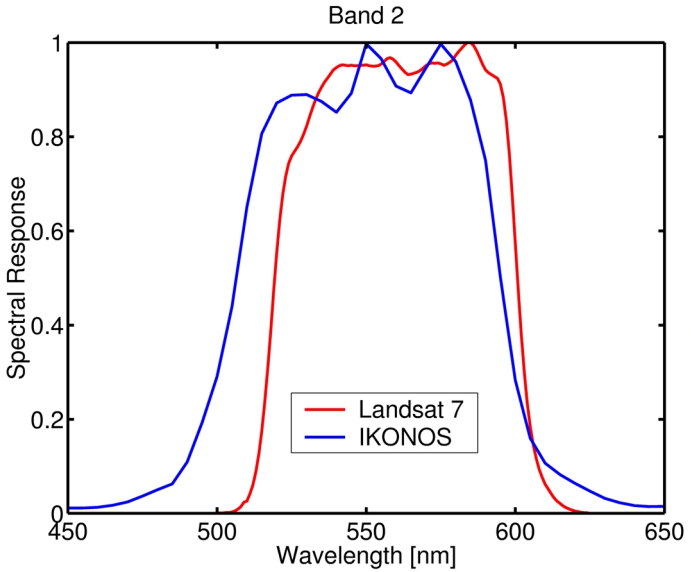
The coefficients c_{ijkl} are found independently for each Landsat 7 pixel by solving (in the least squares sense) for a given set of points (x, y) the following equation which expresses an effective point spread function (PSF') of the Landsat 7 image as a linear combination of the IKONOS image PSF's:

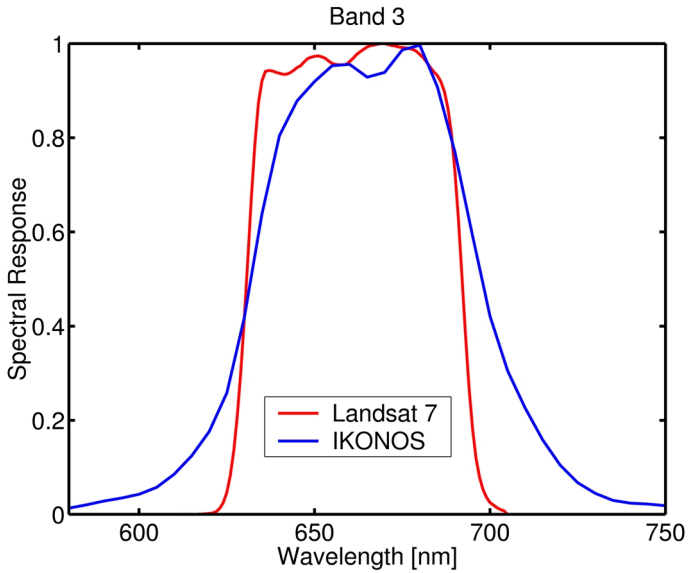
$$PSF'(x - x_l, y - y_k) = \sum_i \sum_j c_{ijkl} PSF(x - x_j, y - y_i)$$

Comparison of Spectral Response

Stennis Space Center







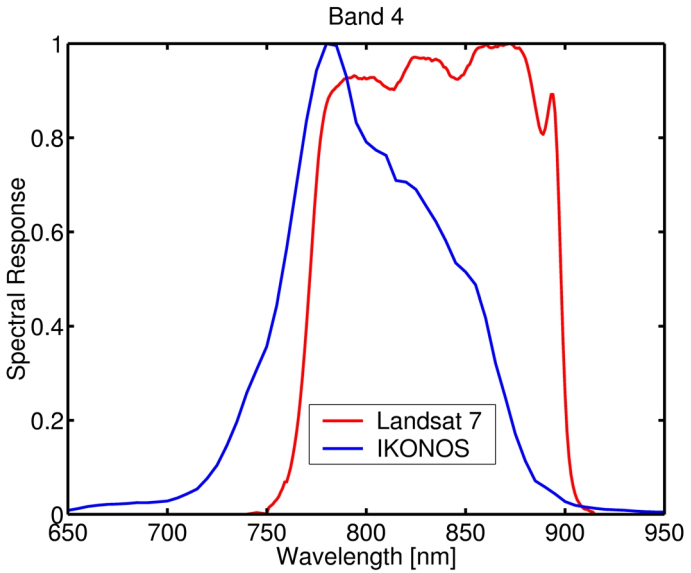
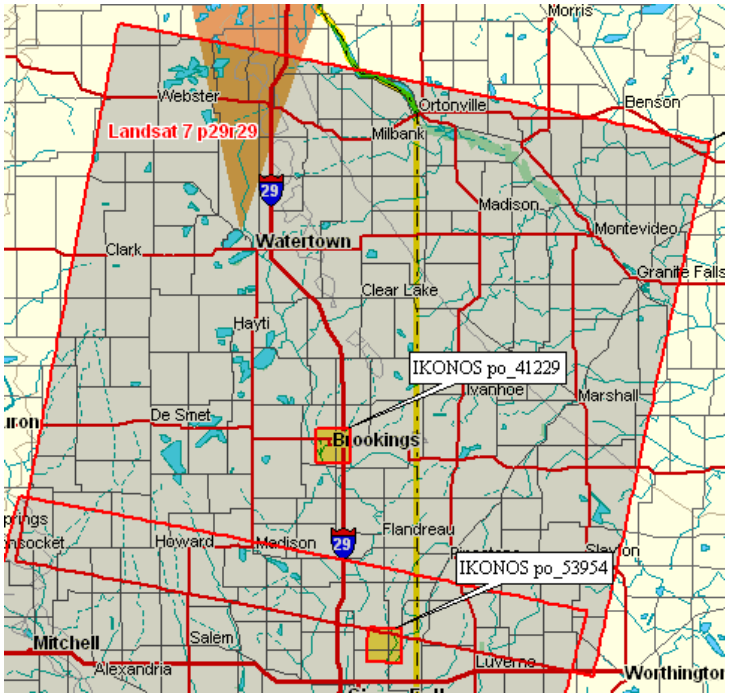


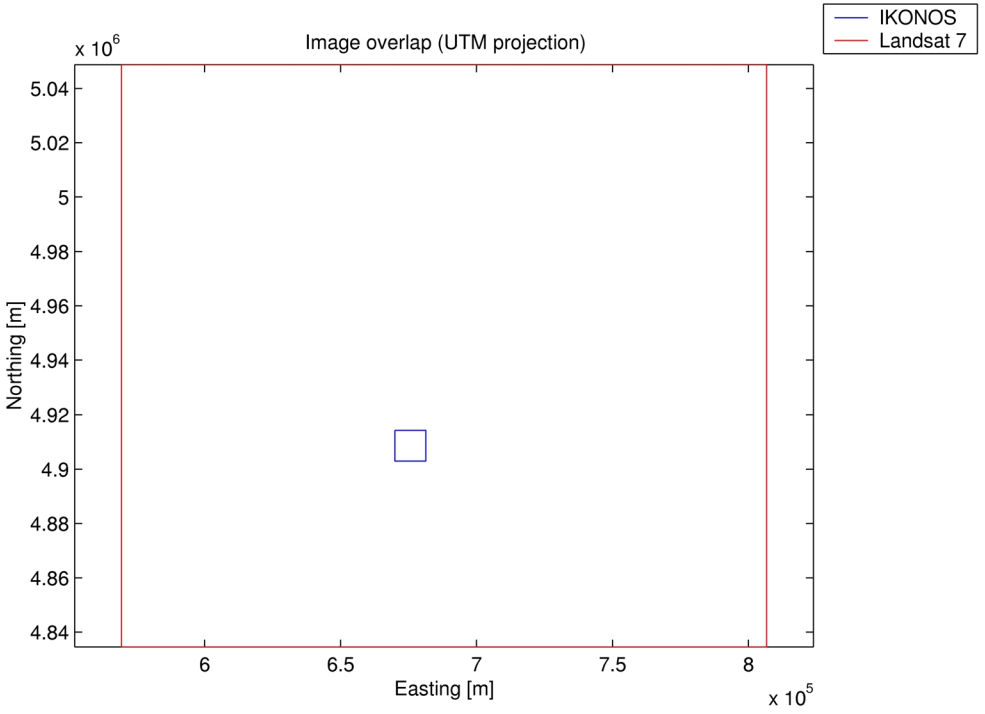
Image Overlap: Brookings, SD

Stennis Space Center

Images acquired on June 30, 2000

- IKONOS
  po_41229 17:12 UTC 4 m GSD
- Landsat 7
  p29r29 17:03 UTC 30 m GSD





Both image products in map orientation (north up)

Geolocation difference

Band 1: 113 m [-11.25, -112.50]
Band 2: 109 m [-11.25, -108.75]
Band 3: 109 m [-11.25, -108.75]
Band 4: 109 m [-7.50, -108.75]

Image Comparison: South Dakota

Actual Landsat 7 image

Simulated Landsat 7 image

Image Detail Comparison

IKONOS image

Simulated Landsat 7 image

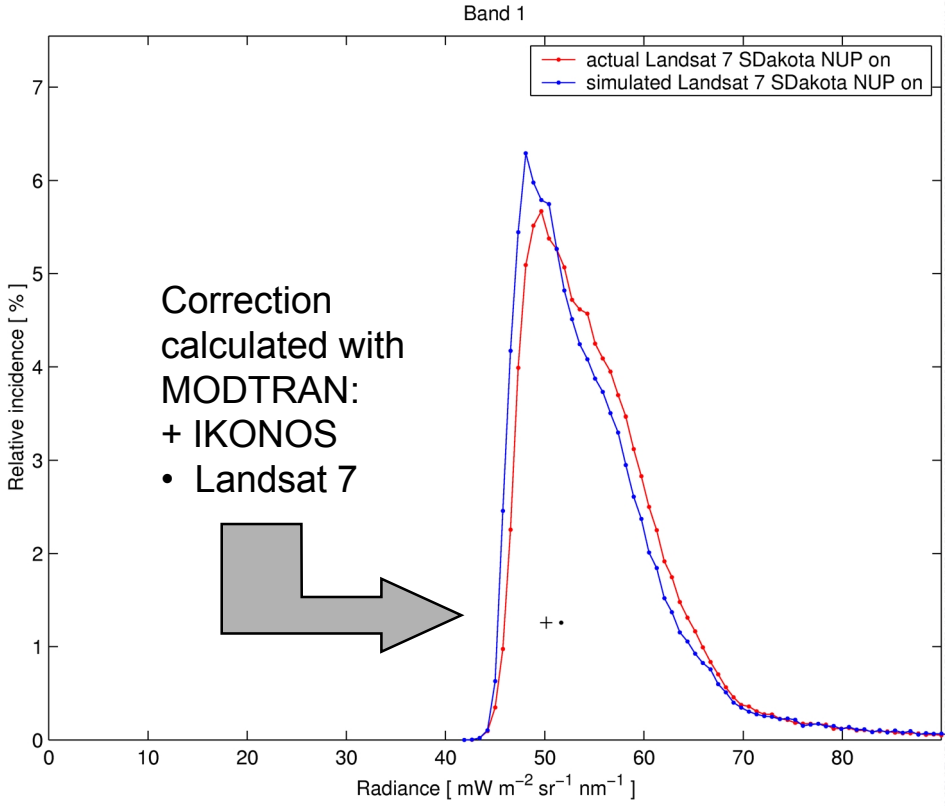
Actual Landsat 7 image

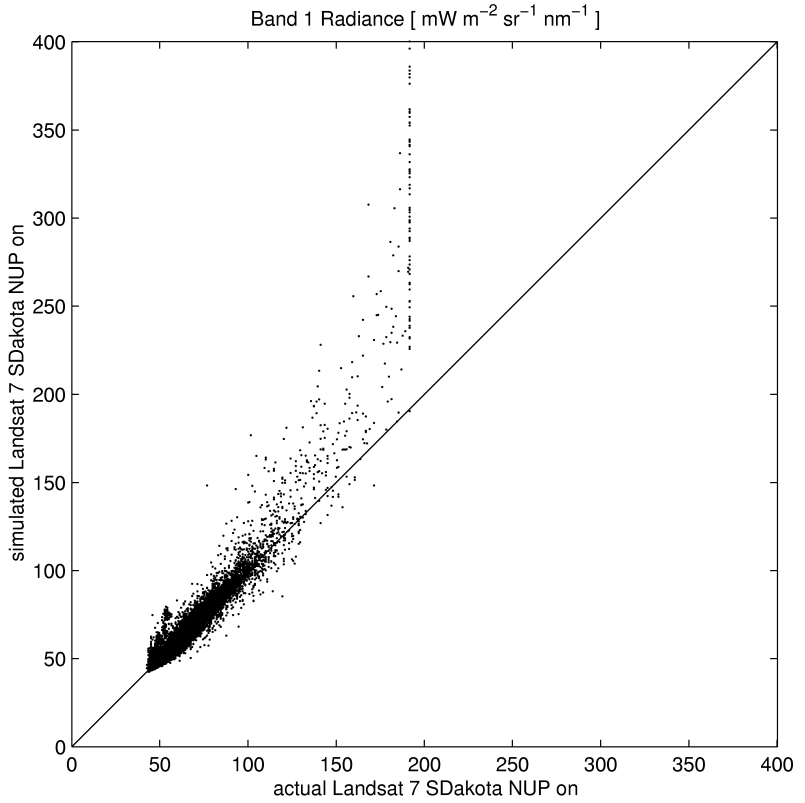
Radiometric Comparison: Band 1

- **Based on updated IKONOS radiometric calibration coefficients:**

  $L = DN / 630\ sr \cdot cm^2 \cdot mW^{-1}$

- **Differences: acquisition time (solar angle), collection geometry (azimuth and elevation angle), spectral response**





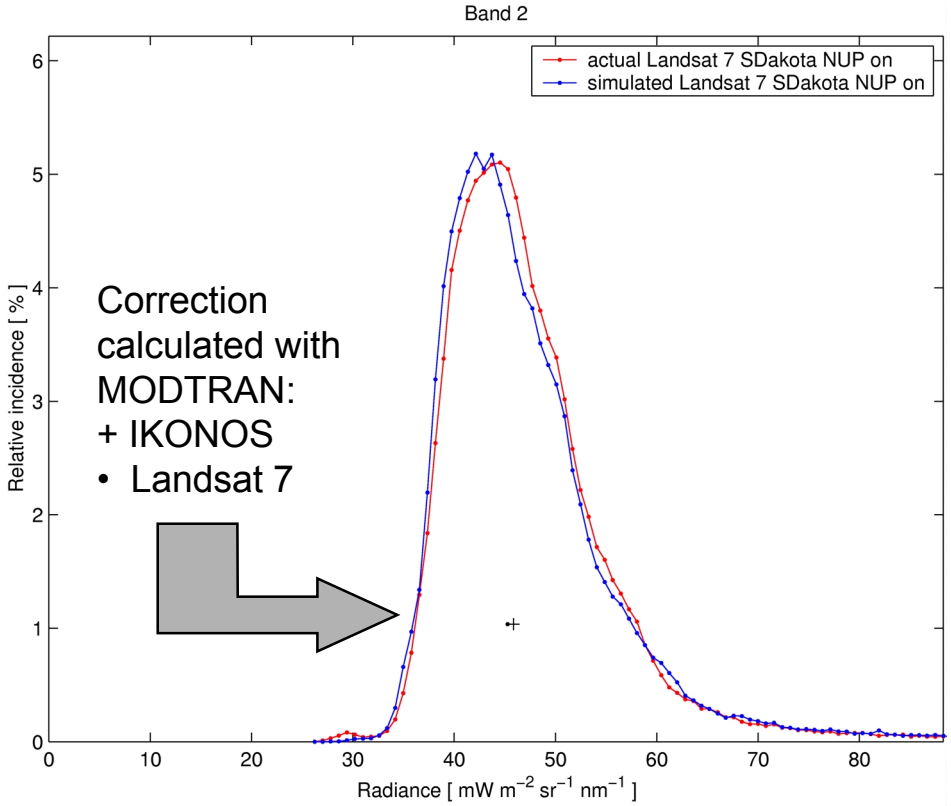
- **Dispersion of points on the scatter plot due to noise and geolocation differences**
- **Presence of saturated Landsat 7 pixels**
- **Nonlinear response of Landsat 7 at higher radiance most likely due to saturation of the original L7 pixels (before resampling to L1G)**

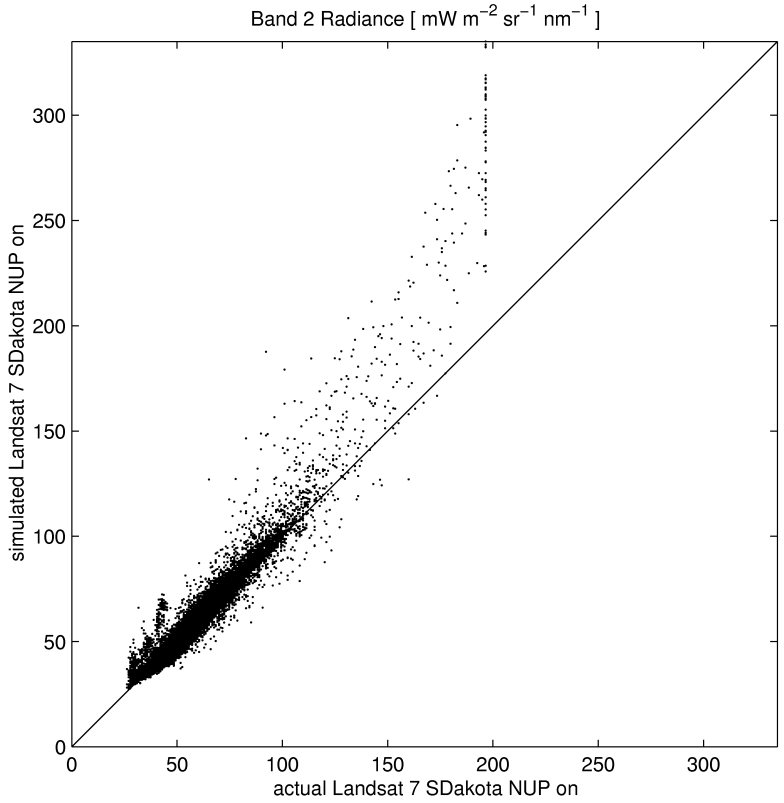
Radiometric Comparison: Band 2

- **Based on updated IKONOS radiometric calibration coefficients:**

  $L = DN / 650\ sr \cdot cm^2 \cdot mW^{-1}$

- **Differences: acquisition time (solar angle), collection geometry (azimuth and elevation angle), spectral response**





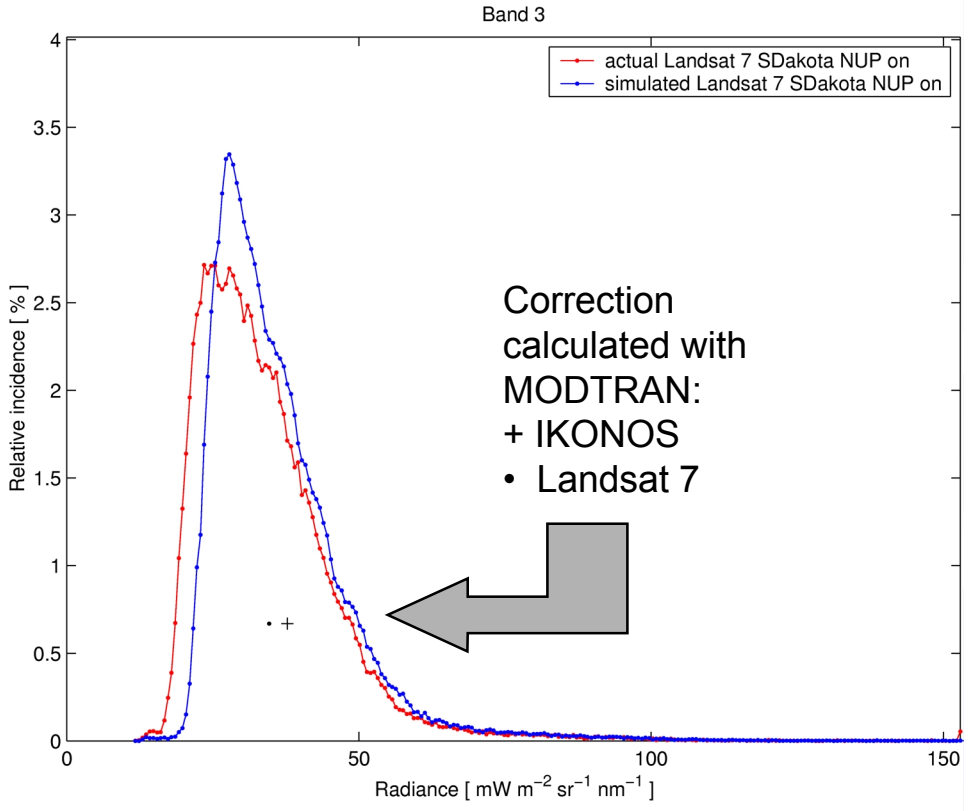
- **Dispersion of points on the scatter plot due to noise and geolocation differences**
- **Presence of saturated Landsat 7 pixels**
- **Nonlinear response of Landsat 7 at higher radiance most likely due to saturation of the original L7 pixels (before resampling to L1G)**

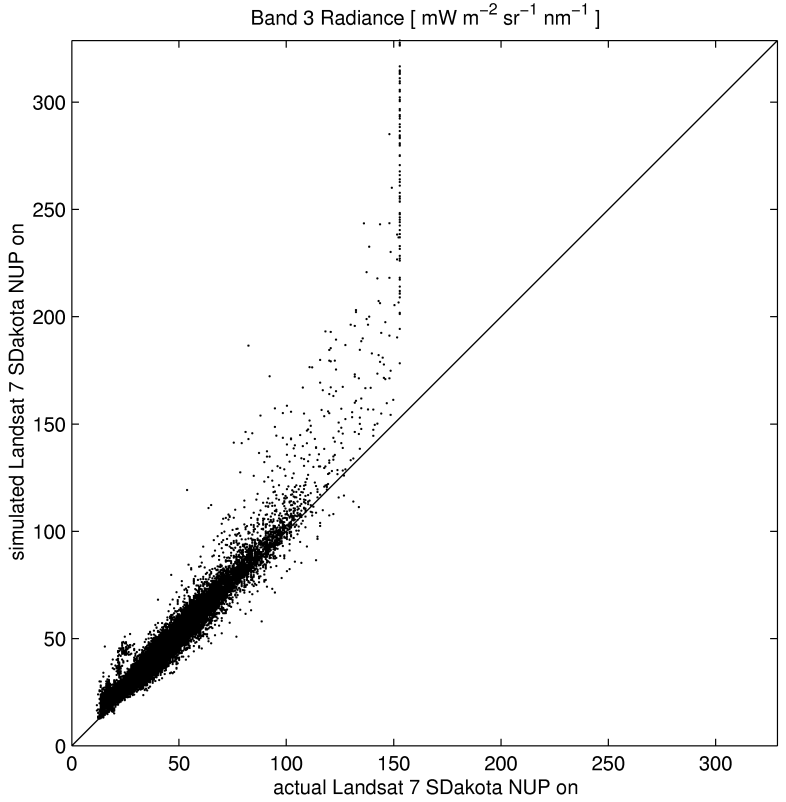
Radiometric Comparison: Band 3

- **Based on updated IKONOS radiometric calibration coefficients:**

  $L = DN / 840\ sr \cdot cm^2 \cdot mW^{-1}$

- **Differences: acquisition time (solar angle), collection geometry (azimuth and elevation angle), spectral response**





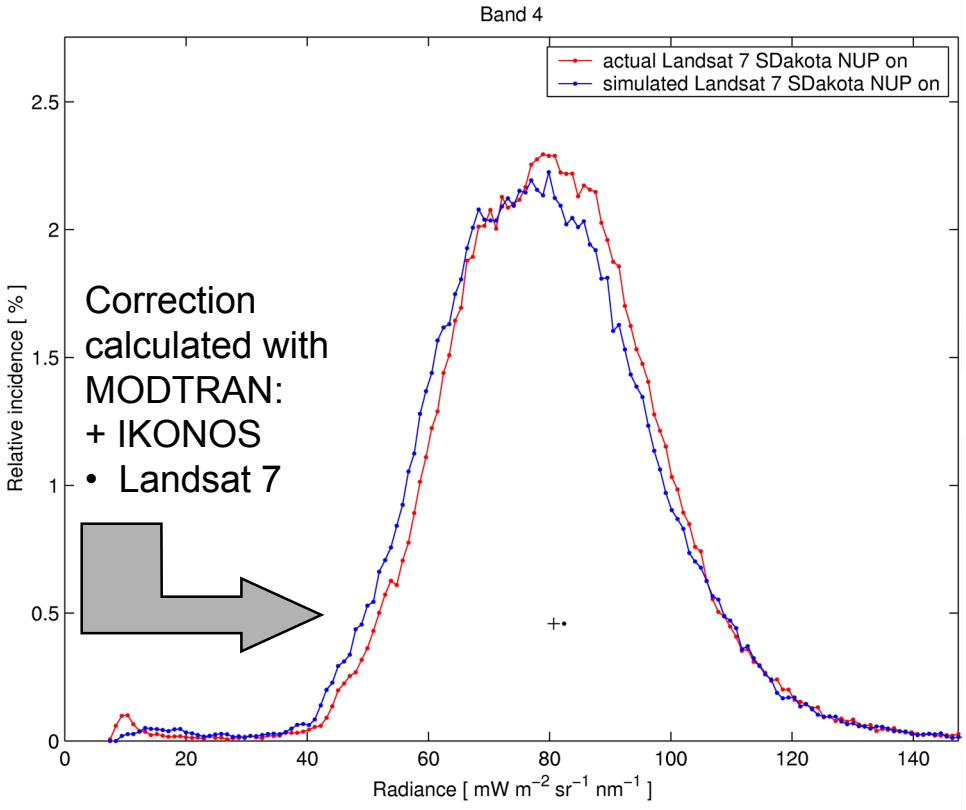
- **Dispersion of points on the scatter plot due to noise and geolocation differences**
- **Presence of saturated Landsat 7 pixels**
- **Nonlinear response of Landsat 7 at higher radiance most likely due to saturation of the original L7 pixels (before resampling to L1G)**

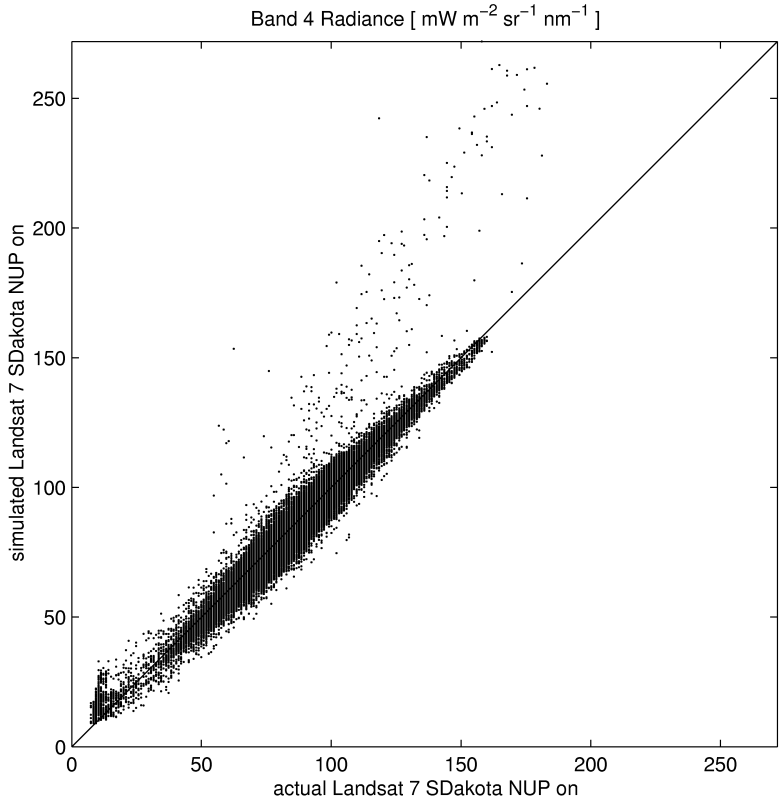
Radiometric Comparison: Band 4

- **Based on updated IKONOS radiometric calibration coefficients:**

  $L = DN / 750\ sr \cdot cm^2 \cdot mW^{-1}$

- **Differences: acquisition time (solar angle), collection geometry (azimuth and elevation angle), spectral response**



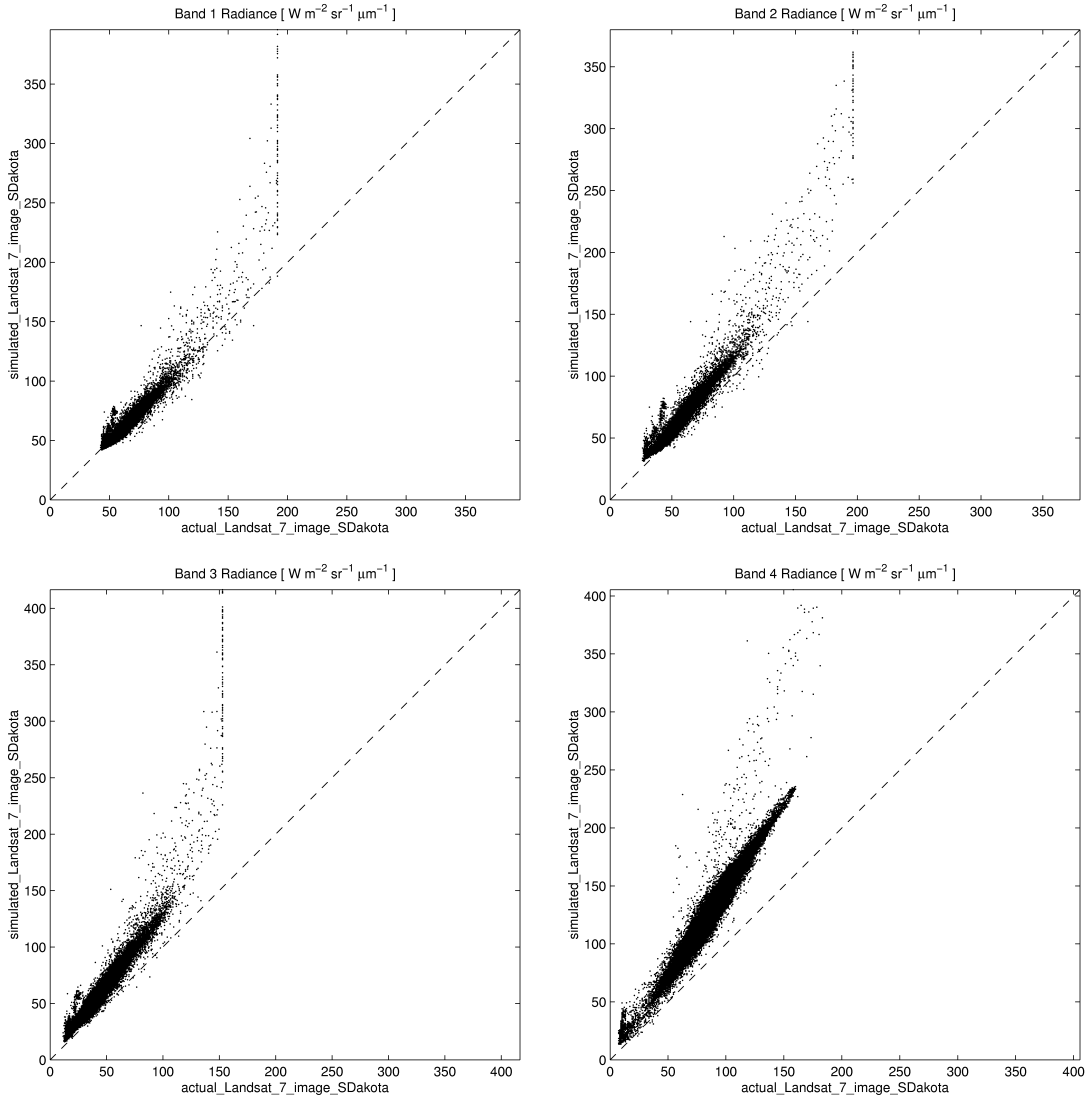


- **Dispersion of points on the scatter plot due to noise and geolocation differences**
- **Nonlinear response of Landsat 7 at higher radiance most likely due to saturation of the original L7 pixels (before resampling to L1G)**

Sensitivity to Radiometric Calibration

Stennis Space Center

Use of initial IKONOS radiometric calibration coefficients result in distorted scatter plots for bands 2, 3, and 4

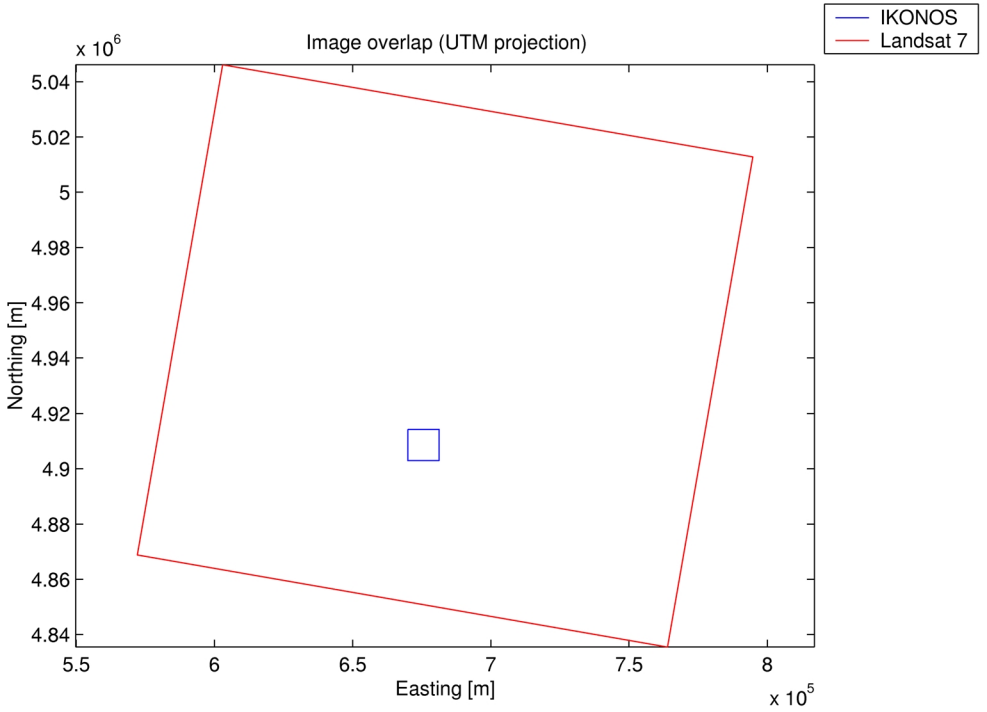


Different Image Orientation

The simulations were also conducted for images with different orientation:

- IKONOS
  - po_41229 17:12 UTC
  - 4 m GSD
  - map (north up) orientation

- Landsat 7
  - p29r29 17:03 UTC
  - 28.5 m GSD
  - nominal (satellite) orientation



Geolocation difference

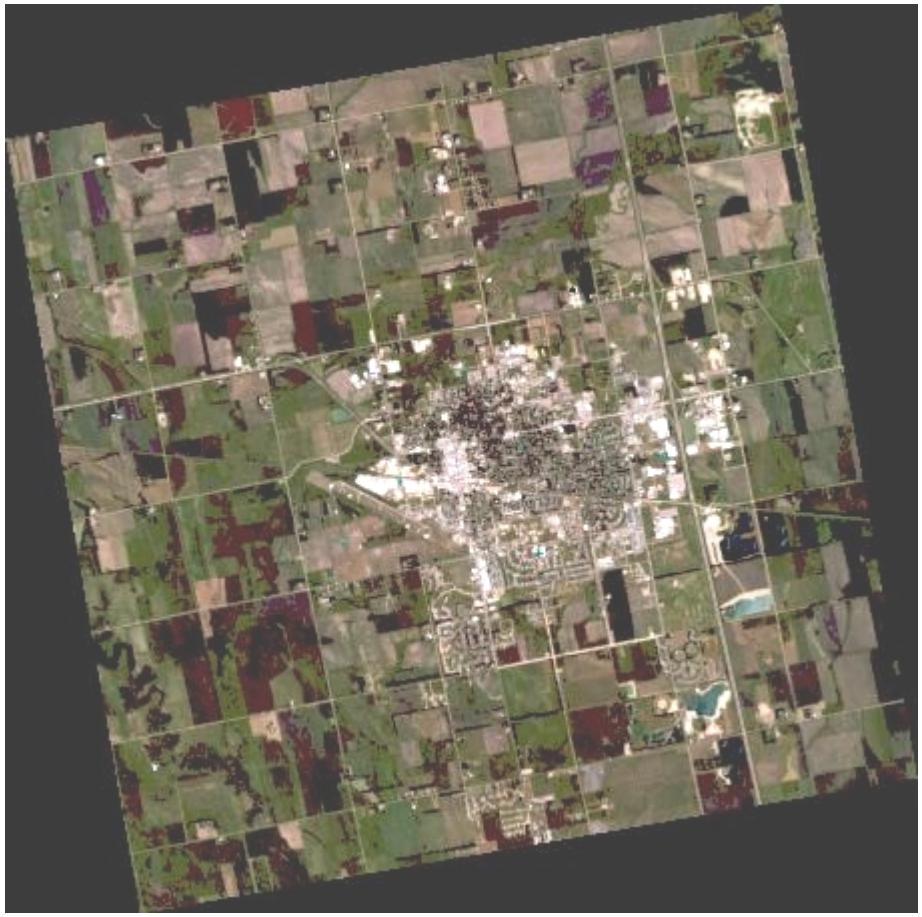
Band 1: 168 m [-14.66, -167.40]
Band 2: 168 m [-14.66, -167.40]
Band 3: 168 m [-14.66, -167.40]
Band 4: 168 m [-14.66, -167.40]

Geolocation difference is still within the limits given by the geometric accuracy of Landsat 7 level 1G and IKONOS standard original image products (250 m)

Image Comparison: Different Orientation

Stennis Space Center

Actual Landsat 7 image

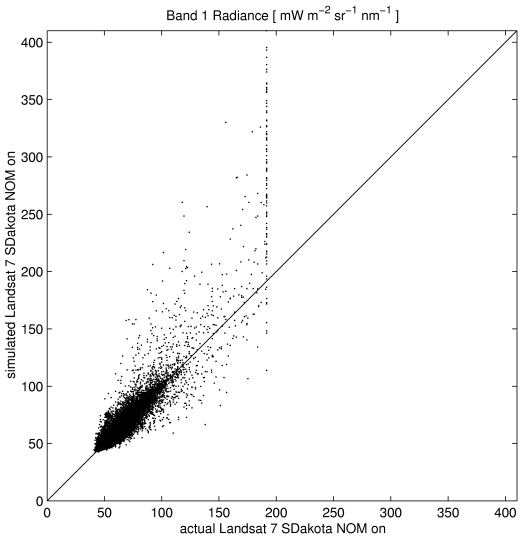


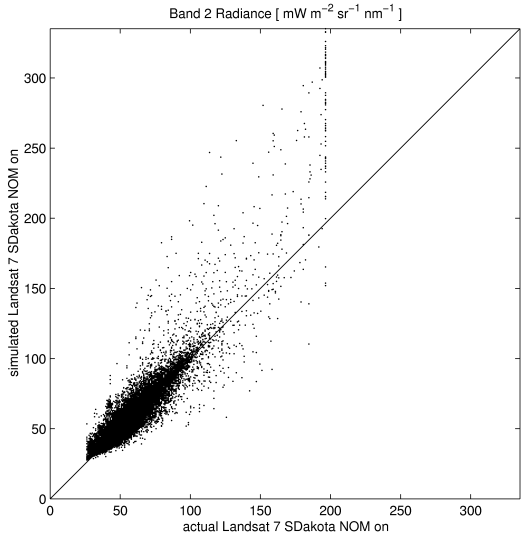
Simulated Landsat 7 image

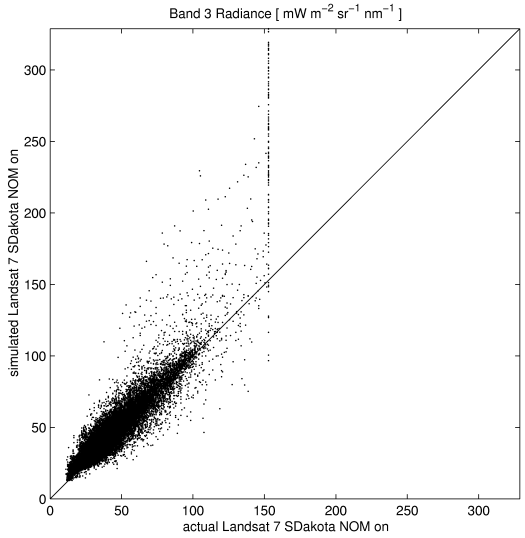
Radiometric Comparison: Orientation

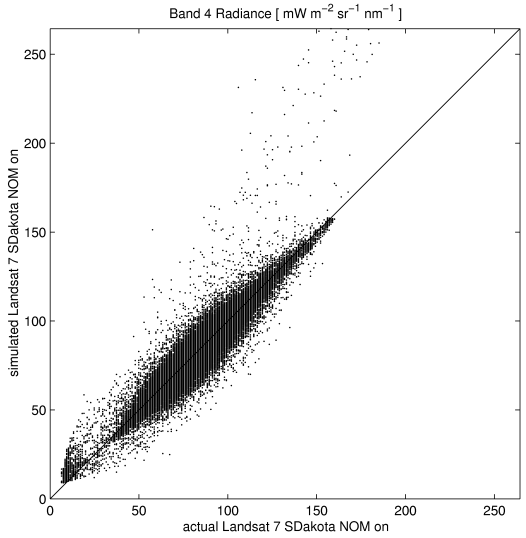
Stennis Space Center

For the case when the input IKONOS image has a different orientation than the output Landsat 7 image, the scatter plots are more dispersed than in the case of images with the same orientation



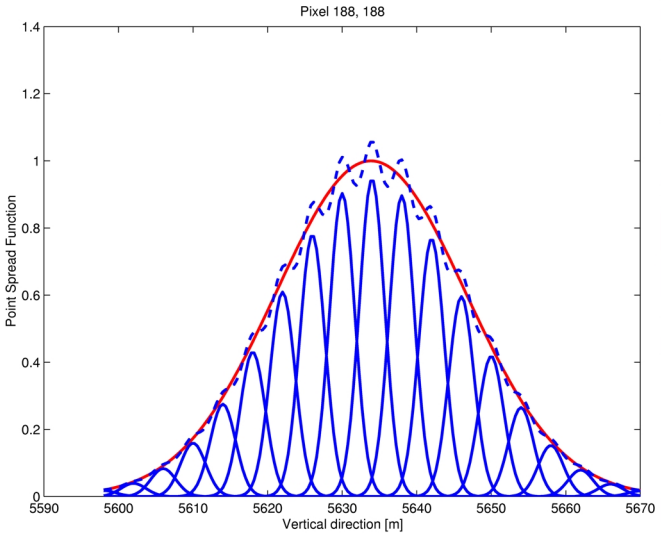




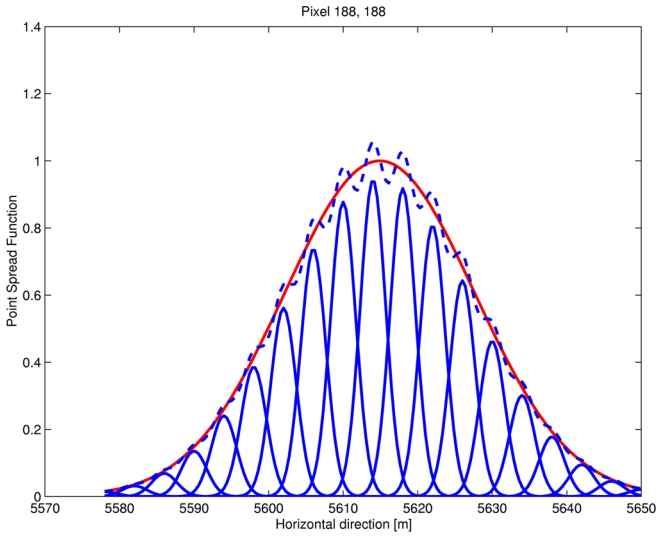


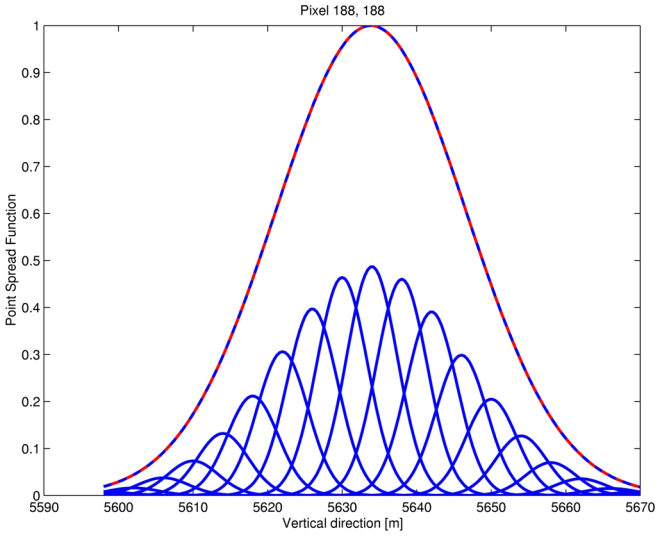
Effect of Spatial Resolution

Stennis Space Center



IKONOS
po_41229
MTFC on
FWHM = 1 GSD





IKONOS
po_53177
MTFC off
FWHM = 2 GSD

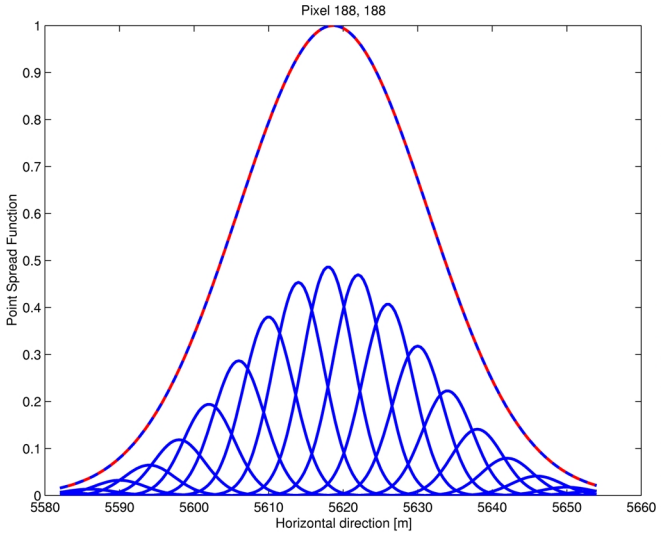


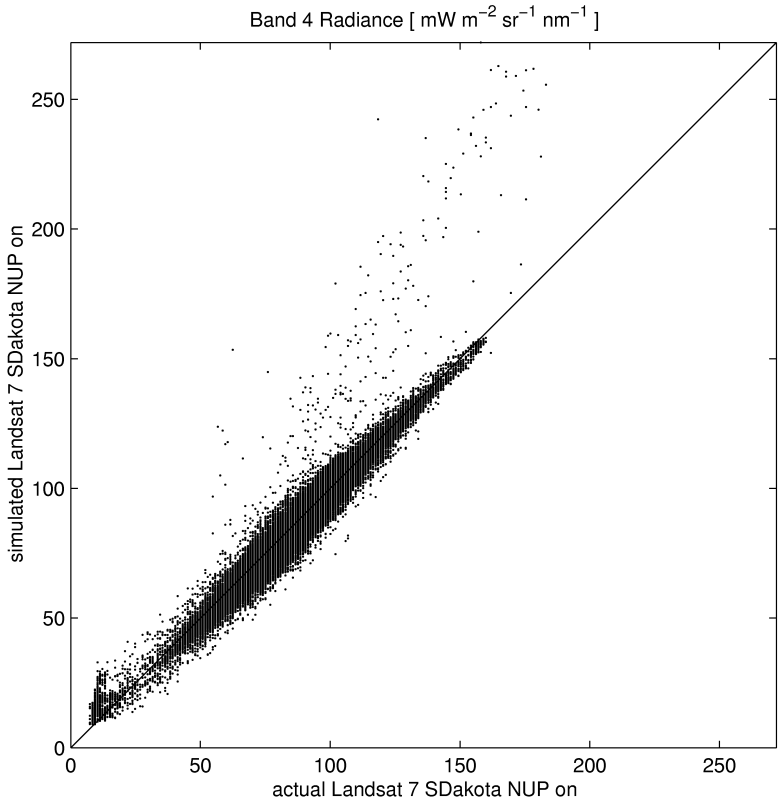
Image Comparison: MTFC On / Off

Simulated Landsat 7 image created from the IKONOS image processed with the MTF compensation

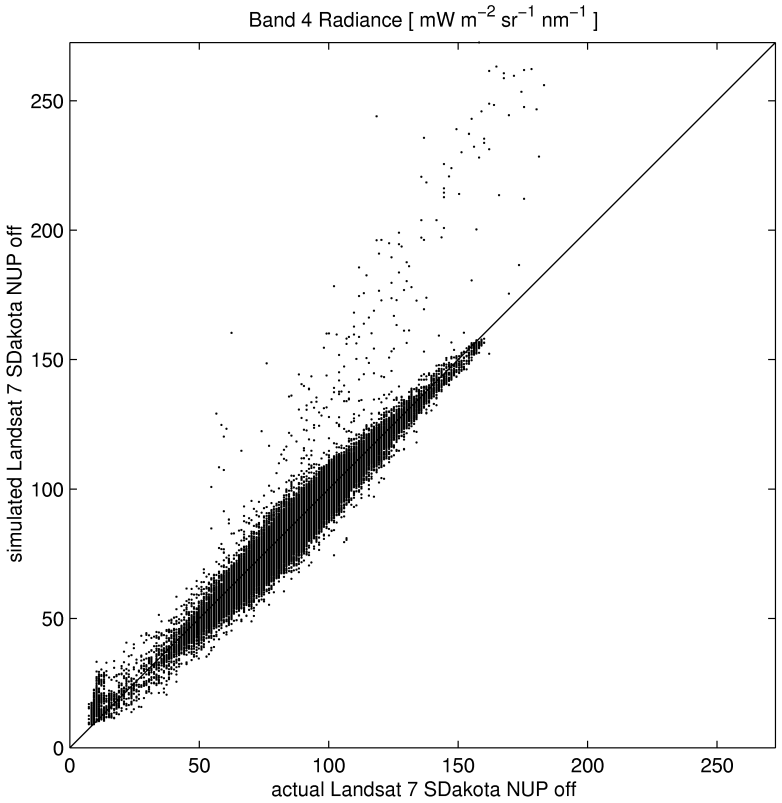
Simulated Landsat 7 image created from the IKONOS image processed without the MTF compensation

Radiometric Comparison: MTFC On / Off

Band 4



MTFC on



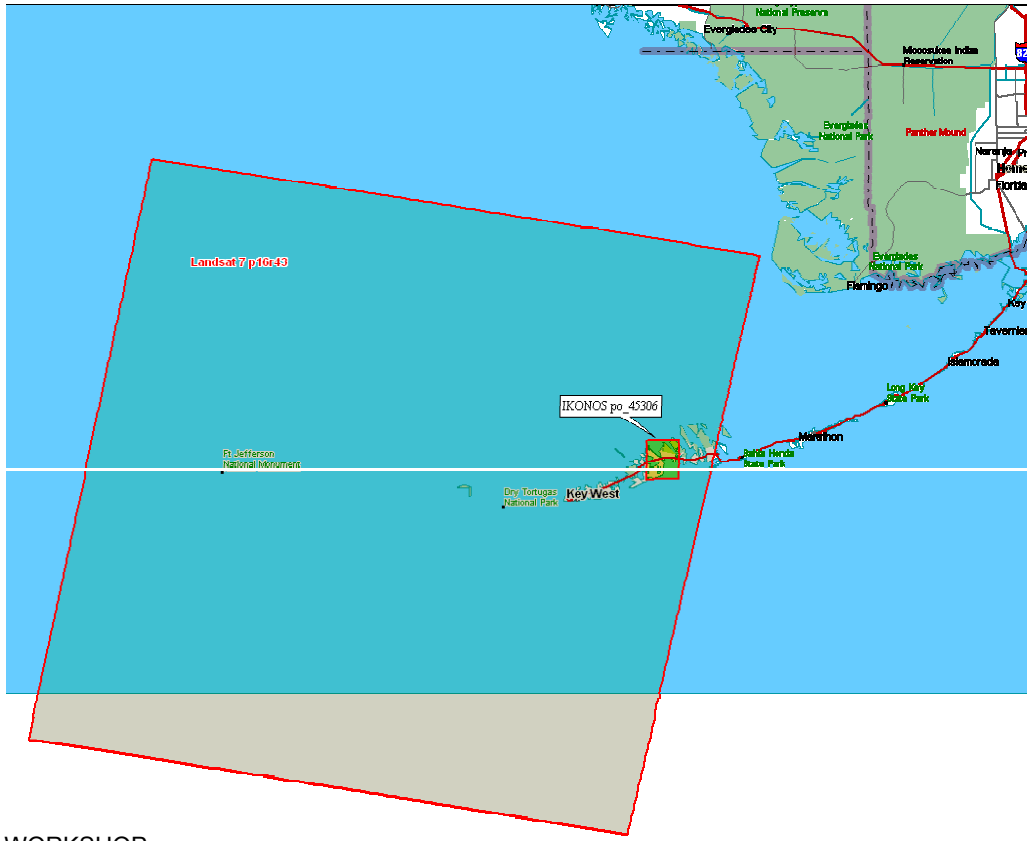
MTFC off

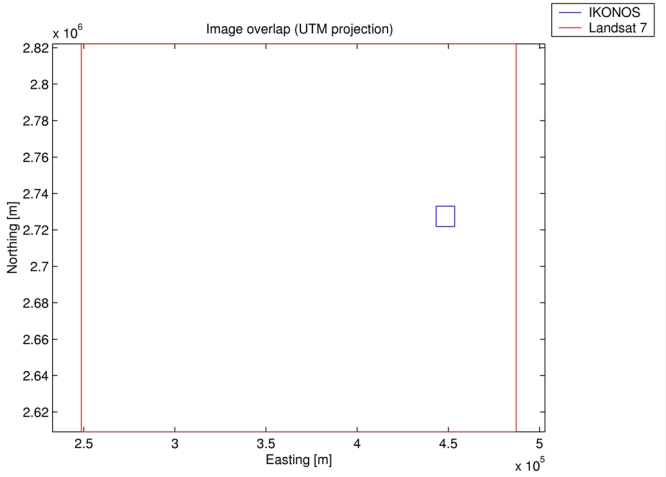
Image Overlap: Florida

Stennis Space Center

Images acquired on September 7, 2000

- IKONOS
  po_45306 15:56 UTC 4 m GSD
- Landsat 7
  p16r43 15:47 UTC 30 m GSD





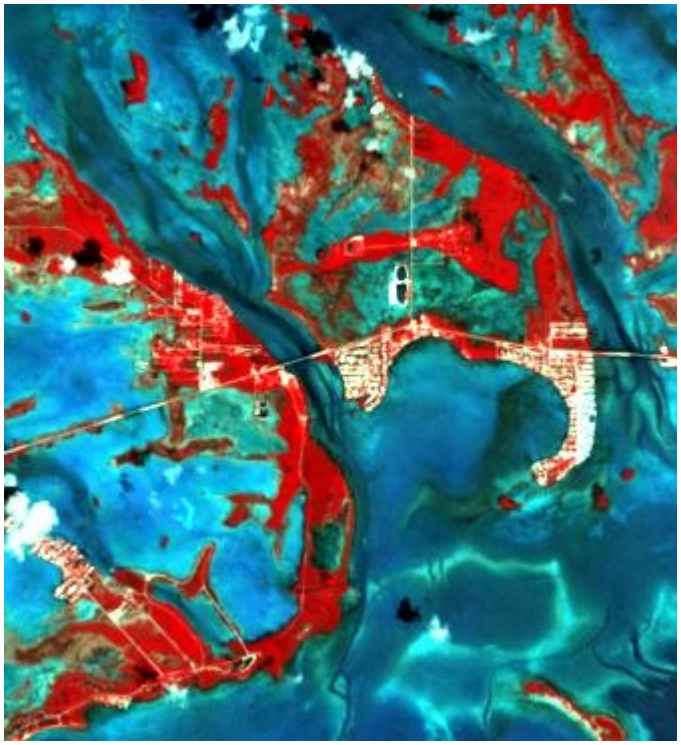
Both image products in map (north up) orientation

Geolocation difference

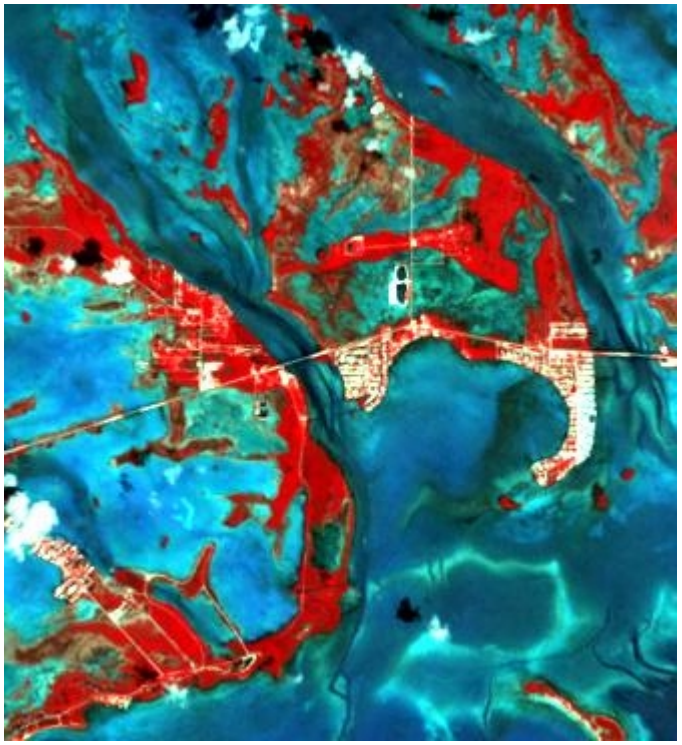
Band 1: 0 m
Band 2: 0 m
Band 3: 0 m
Band 4: 0 m

Image Comparison: Florida

Stennis Space Center



Actual Landsat 7 image

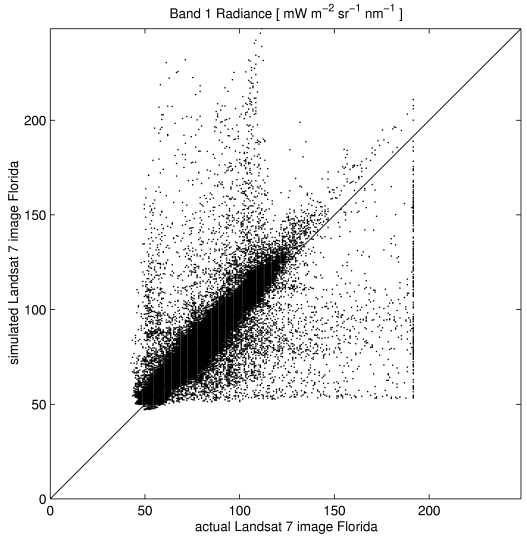


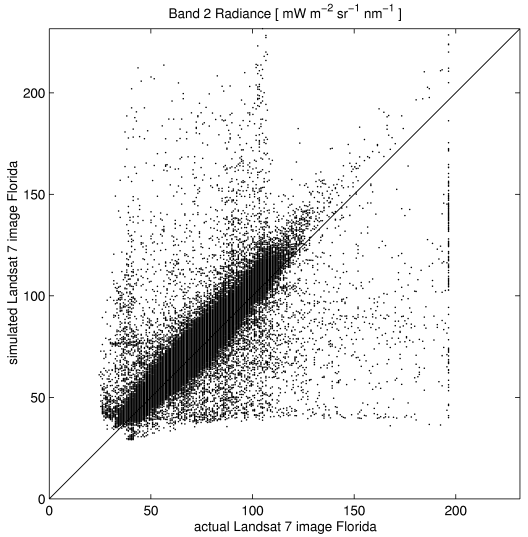
Simulated Landsat 7 image

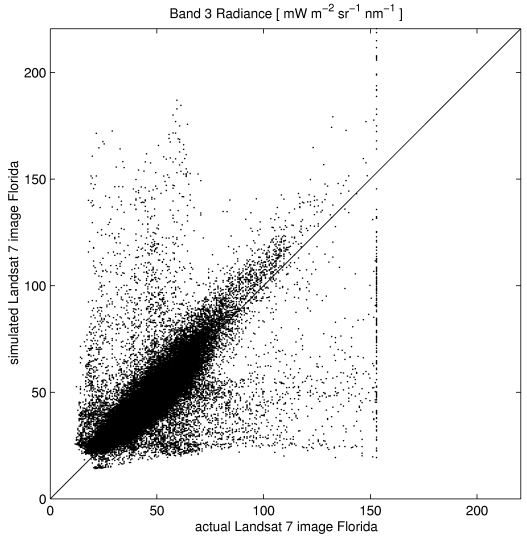
Radiometric Comparison: Florida

Stennis Space Center

Orthogonal streaks are due to development and movement of clouds during the time between acquisitions of the two images







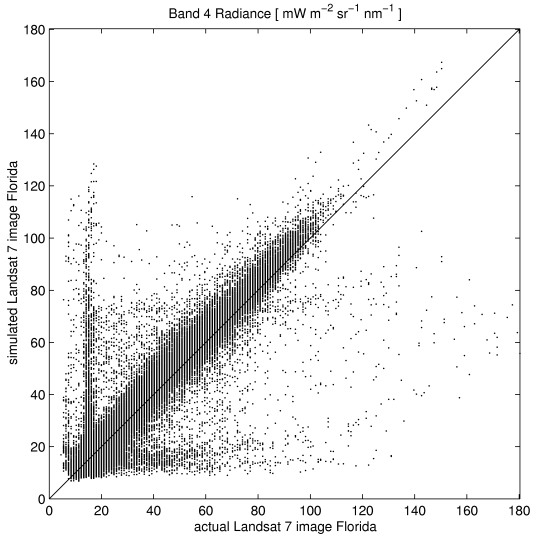
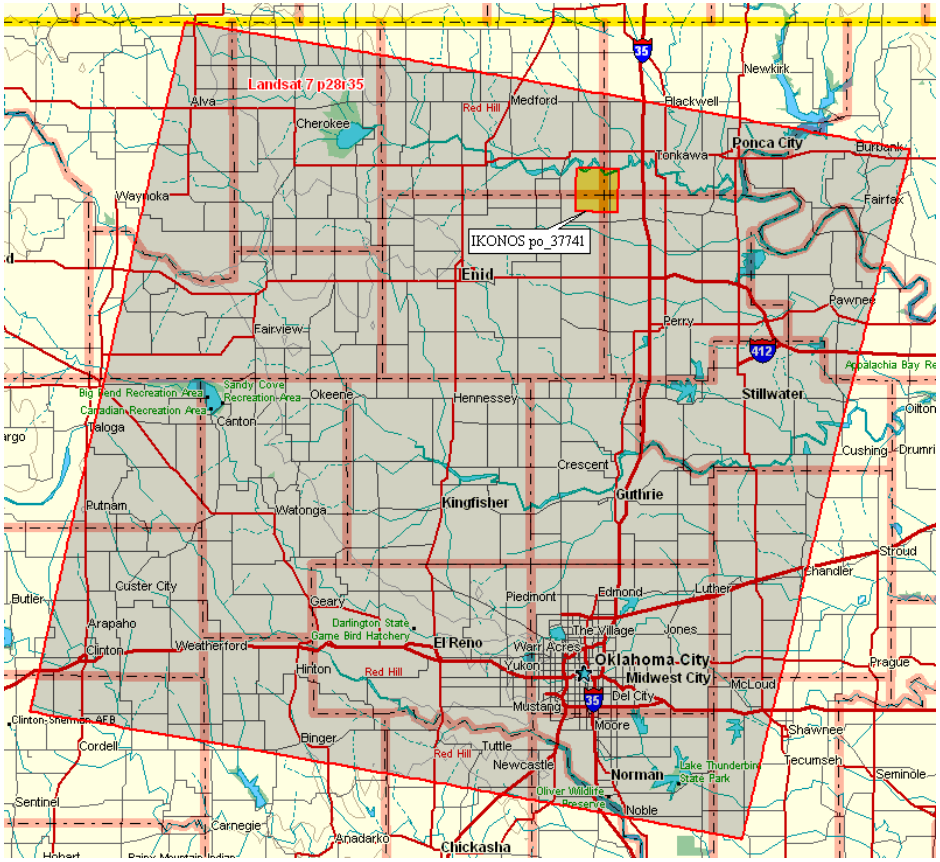


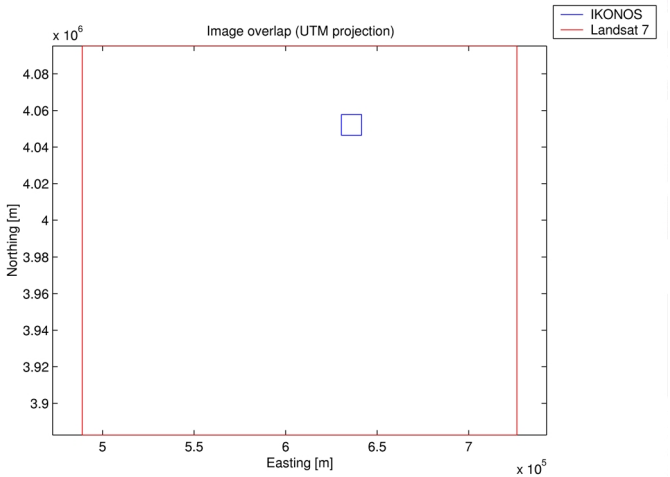
Image Overlap: Oklahoma

Stennis Space Center

Images acquired on May 22, 2000

- IKONOS
  po_37741 16:52 UTC 4 m GSD
- Landsat 7
  p28r35 16:59 UTC 30 m GSD





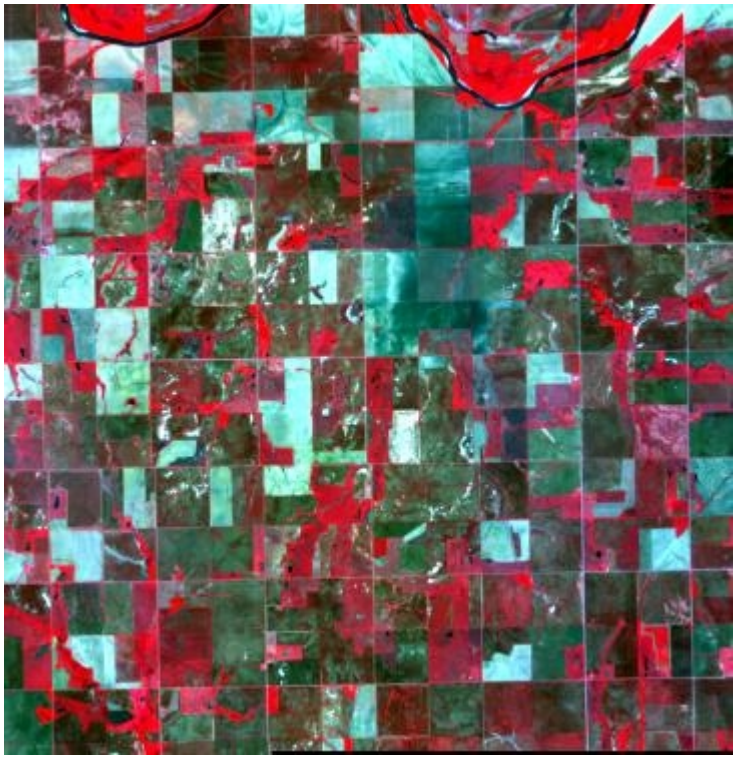
Both image products in map (north up) orientation

Geolocation difference

Band 1: 0 m
Band 2: 0 m
Band 3: 0 m
Band 4: 0 m

Image Comparison: Oklahoma

Actual Landsat 7 image



Simulated Landsat 7 image

Radiometric Comparison: Oklahoma

Stennis Space Center

Difference in atmospheric conditions (high cirrus clouds) resulted in attenuation of Landsat 7 at-sensor radiance and increased scattering

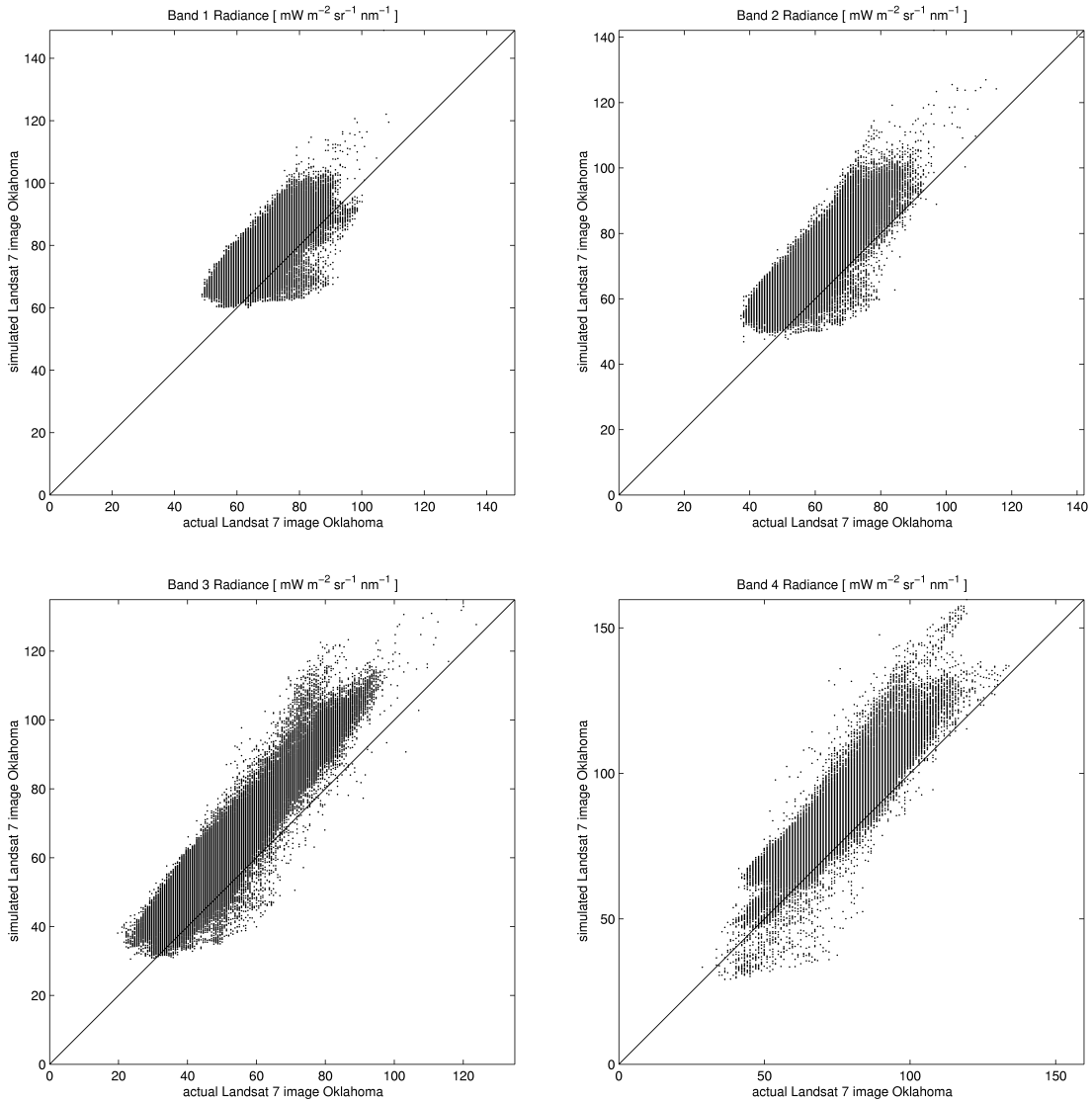
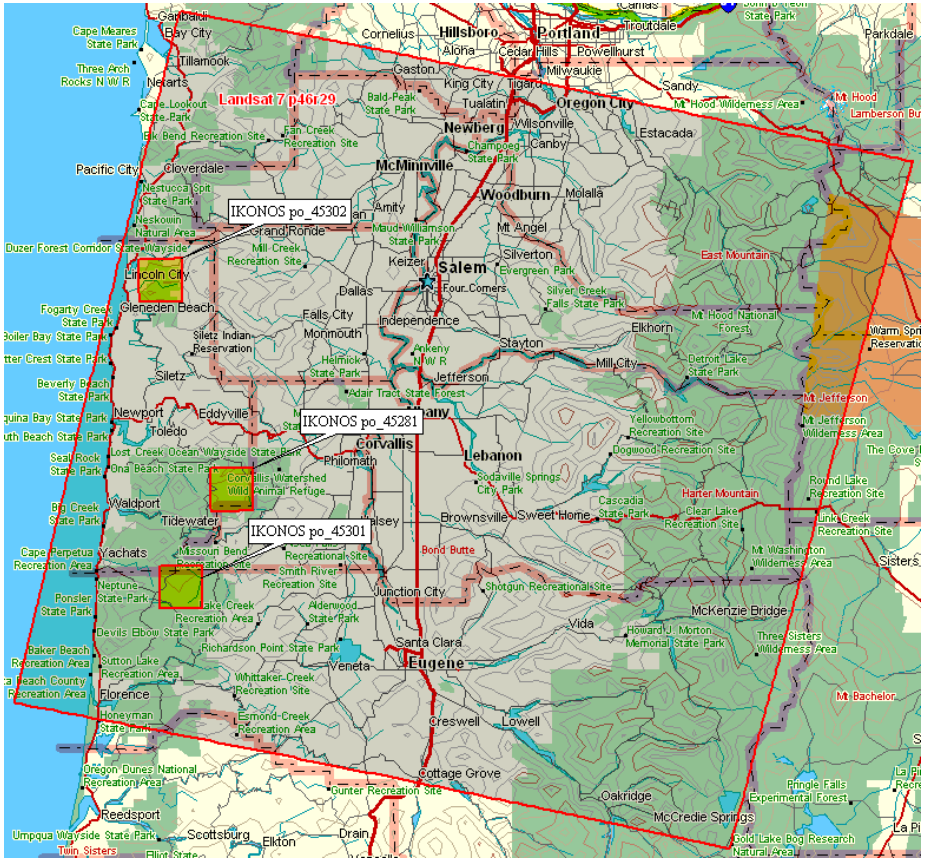
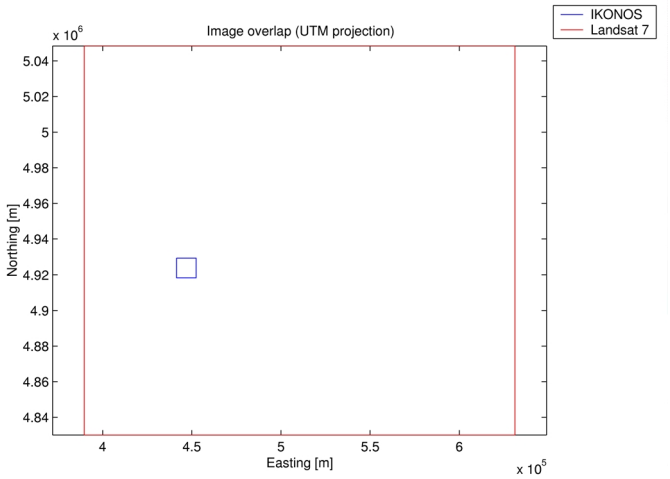


Image Overlap: Oregon

Images acquired on August 8, 2000

- IKONOS
  po_45281 19:13 UTC 4 m GSD
- Landsat 7
  p46r29 18:47 UTC 30 m GSD





Both image products in map (north up) orientation

Geolocation difference

Band 1:	47 m	[45.00, -15.00]
Band 2:	51 m	[48.75, -15.00]
Band 3:	47 m	[45.00, -15.00]
Band 4:	47 m	[45.00, -15.00]

Image Comparison: Oregon

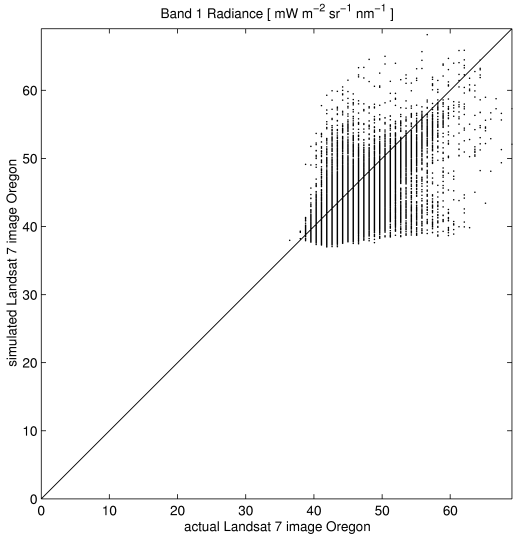
Actual Landsat 7 image

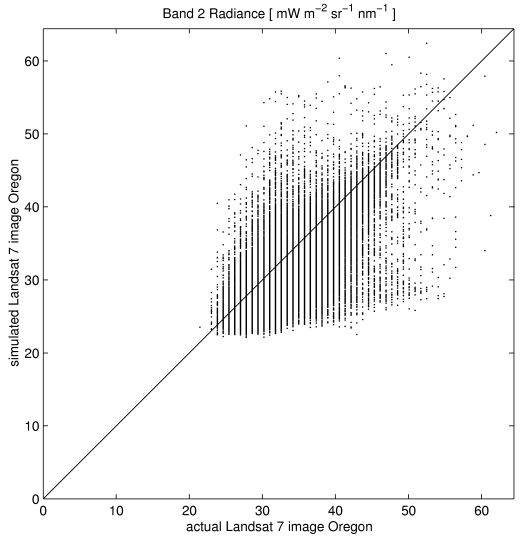
Simulated Landsat 7 image

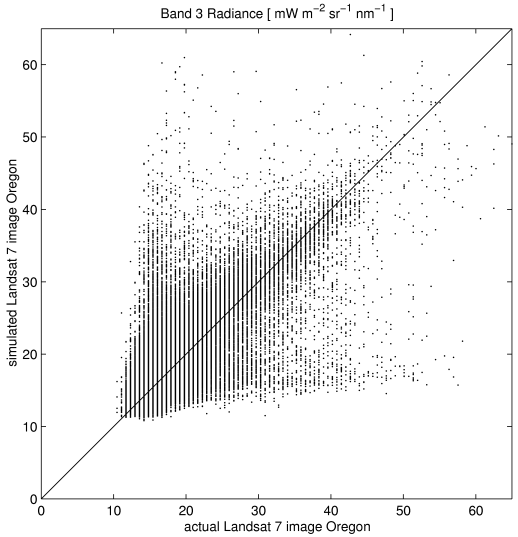
Radiometric Comparison: Oregon

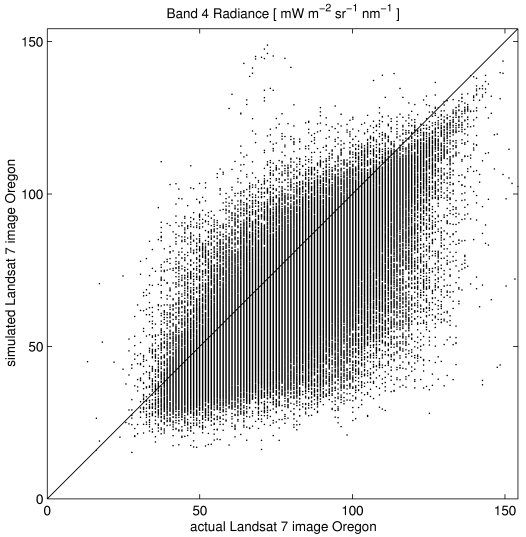
Stennis Space Center

Local differences in pixel geolocation create characteristic dispersion in the scatter plots









Final Remarks

- **IKONOS images can be accurately transformed to mimic VNIR image data created by Landsat 7**
- **Mitigation of effects created by differences in acquisition time (solar angle), collection geometry (azimuth and elevation angle), and spectral response may be needed to achieve the accurate results**
- **The simulations become less accurate when atmospheric conditions are different (clouds) or when terrain relief creates local geolocation differences**